[公开]

中国原子能科学研究院
中核集团 CNNC
CHINA INSTITUTE OF ATOMIC ENERGY

High-spin states in even-even ^{204}Po and competition among various excitation modes

TOPTIER CNS Summer school

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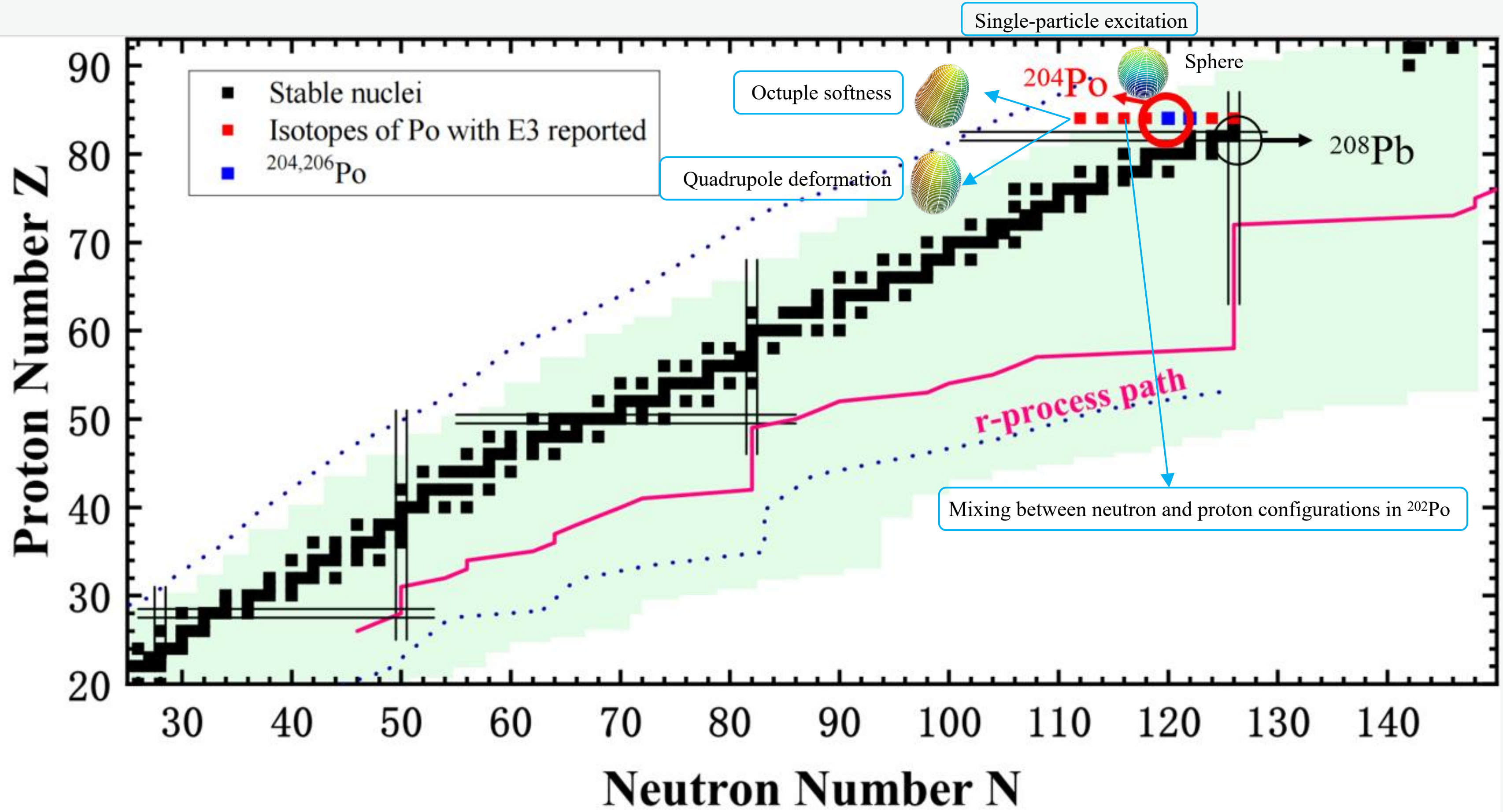
1.1 Introduction



1.1 Introduction

By contrast, in ^{204}Po and ^{206}Po, its decay changes to E1, and no E3 transition is observed experimentally.

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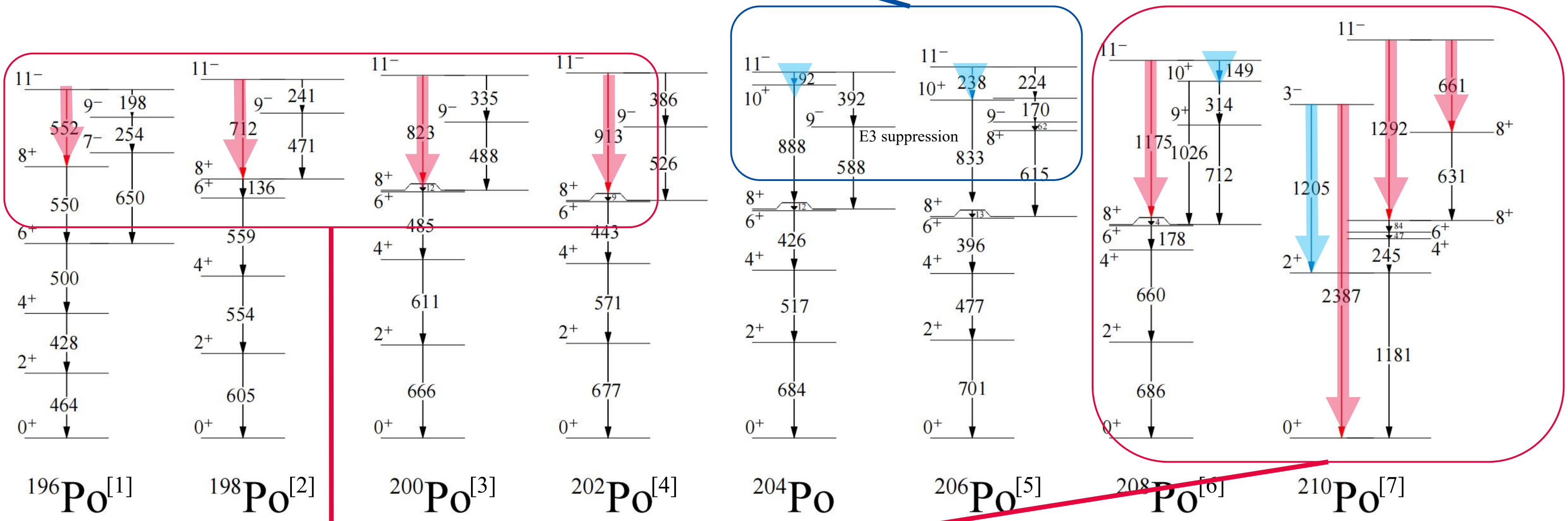

On both the neutron-rich and neutron-deficient sides, 11^- state mainly de-excites through E3 .

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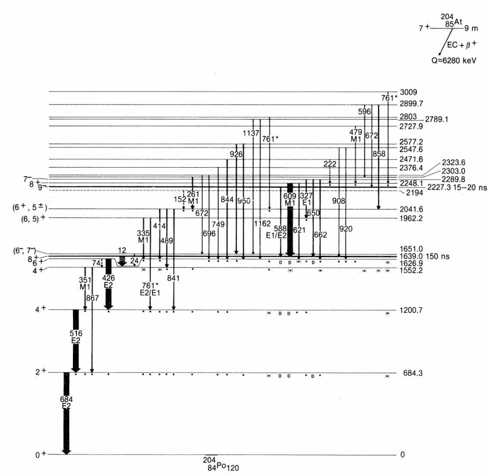
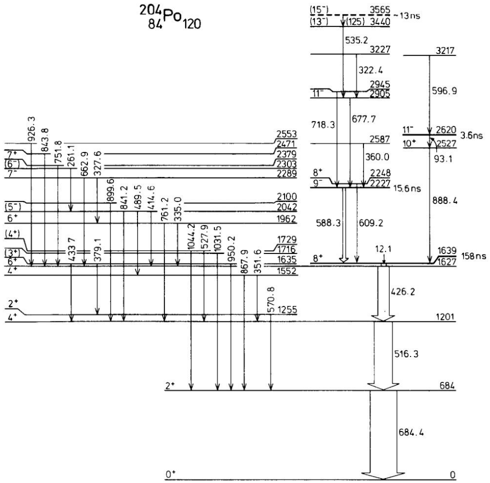
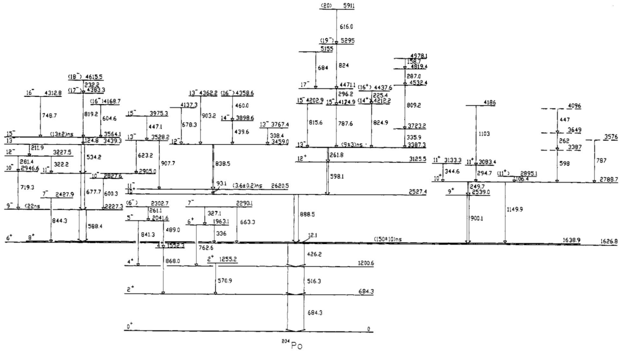
1.2 Previous Studies of ^{204}Po







1983, R. G. Helmer and C. W. Reich

1987, V. Rahkonen and T. Lonnroth

1990, B. Fant and T. Weckstrom

R. G. Helmer and C. W. Reich, Phys. Rev. C, Vol 27, Num 5(1983).

V. Rahkonen and T. Lonnroth, Nuclear Physics A464 (1987) 349-365

B. Fant and T. Weckstrom , Physica Scripta. Vol. 41, 652-659, 1990.

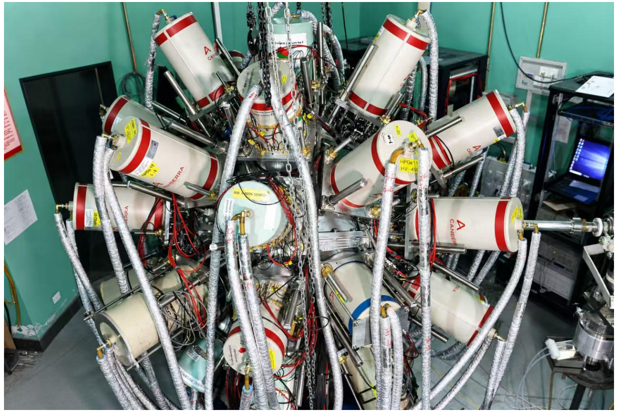
By observing the β-decay of ^{204}At, they determined the low-spin energy level structure of ^{204}Po, resolved the uncertainty in the energy of the 8^{+} first excited state, and measured its lifetime to be approximately 150(10) ns.

By bombarding ^{204}Pb with ^{3}He, they populated the medium-to-low spin states of ^{204}Po; new isotopic spin states such as 9- and 11- were observed; their lifetimes were determined; and for the first time, it was proposed that the first excited state of 11- undergoes deexcitation to the 10+ state via an E1 transition at 93 keV.

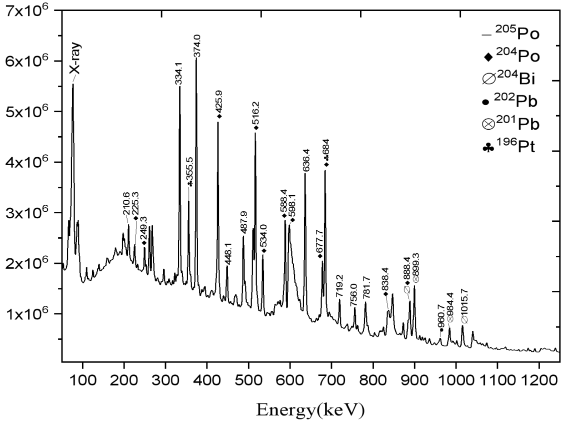
Through a fusion-evaporation reaction involving the bombardment of ^{198}Pt with ^{12}C, the high-spin nuclear structure of ^{204}Po was populated for the first time; an excited state with a maximum spin of 20^{+} was observed.

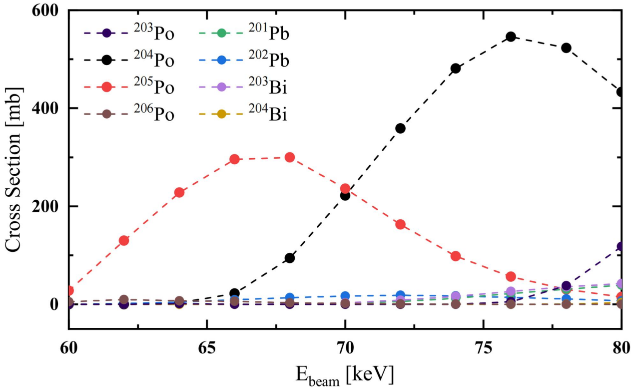
Experimental investigations of Po two zero four (204Po) are rather extensive, using decay spectroscopy and fusion-evaporation reactions. However, even with fusion-evaporation experiments performed by 1990, many cascade connections in its level structure were still uncertain.

2 Experiment Brief



Detectors Array



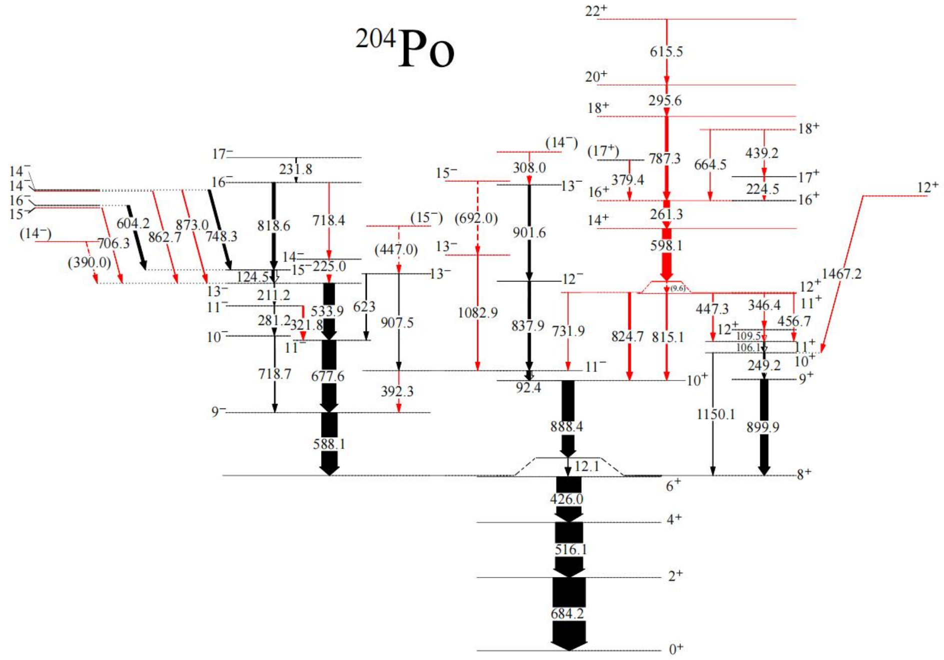


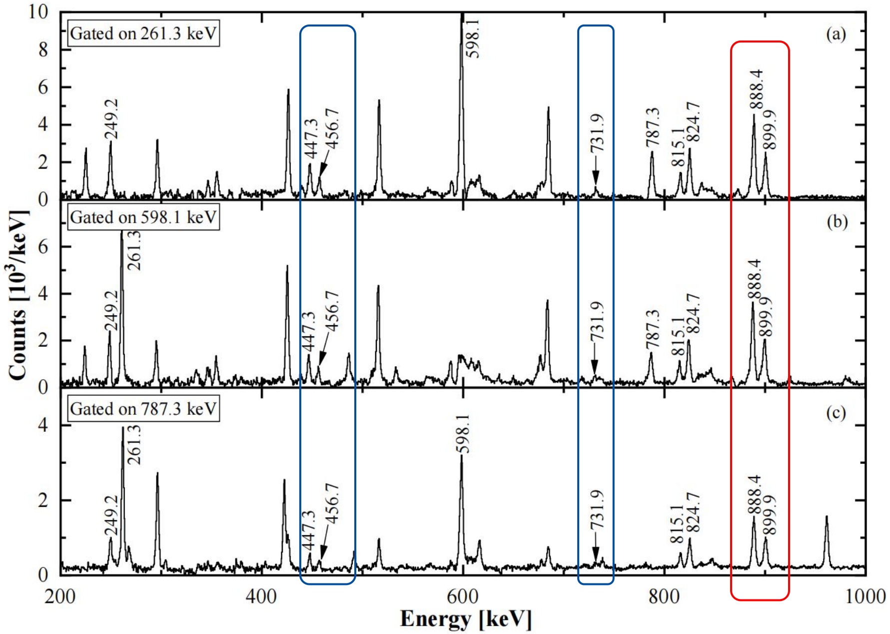
- Beijing Radioactive Ion beam Facility (BRIF), HI-13 tandem accelerator
- $^{13}C+^{196}Pt \rightarrow ^{204}Po+5n$
- 1.34mg/cm^2 Self-supporting target + 78 MeV Beam
- 28*HPGe + 5*Clover detectors
- 60 hours

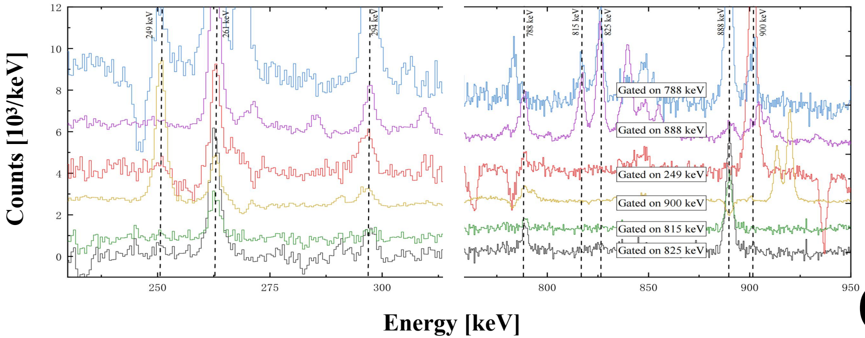
mod-ch[a]	Code Number[b]	Name	θ	Resolution[c]
00-04	0	HPGE-3	90	4.64
00-05	1	HPGE-9	90	5.43
00-06	2	HPGE-13	60	3.84
00-07	3	HPGE-14	60	3.84
00-12	4	HPGE-27	120	2.67
00-13	5	HPGE-28	120	4.04
00-14	6	HPGE-35	150	3.65
00-15	7	HPGE-36	150	2.51
01-04	8	HPGE-33(weak signal)	120	2.52
01-05	9	HPGE-37	150	3.60
01-06	10	HPGE-15	60	2.63
01-07	11	HPGE-16	60	2.76
01-12	12	HPGE-30	120	3.74
01-13	13	HPGE-31	120	4.01
01-14	14	HPGE-38	150	
01-15	15	HPGE-39	150	5.82
02-04	16	HPGE-5	90	
02-05	17	HPGE-18	60	3.41
02-06	18	HPGE-19	60	3.03
02-07	19	HPGE-20	60	3.13
02-12	20	HPGE-32	120	2.76
02-13	21	HPGE-34	120	2.63
02-14	22	HPGE-40	150	3.37
02-15	23	HPGE-1	90	3.49
03-12	24	Clover-2-a	90	
03-13	24	Clover-2-b	90	
03-14	24	Clover-2-c	90	
03-15	24	Clover-2-d	90	
04-04	25	Clover-12-a	90	
04-05	25	Clover-12-b	90	
04-06	25	Clover-12-c	90	
04-07	25	Clover-12-d	90	
04-12	26	Clover-29-a	120	
04-13	26	Clover-29-b	120	
04-14	26	Clover-29-c	120	
04-15	26	Clover-29-d	120	
05-04	27	Clover-10-a	90	
05-05	27	Clover-10-b(no signal)	90	
05-06	27	Clover-10-c	90	
05-07	27	Clover-10-d	90	
05-12	28	Clover-11-a	90	
05-13	28	Clover-11-b(no signal)	90	
05-14	28	Clover-11-c	90	
05-15	28	Clover-11-d(no signal)	90	
06-04	29	Clover-8-a	90	
06-05	29	Clover-8-b	90	
06-06	29	Clover-8-c	90	
06-07	29	Clover-8-d	90	
06-12	30	Clover-4-a	90	
06-13	30	Clover-4-b	90	
06-14	30	Clover-4-c	90	
06-15	30	Clover-4-d	90	

[a] The signal channel.
[b] The encoding used in code.
[c] Resolutions at energy(to be confirmed) keV, per thousandth of the unit.

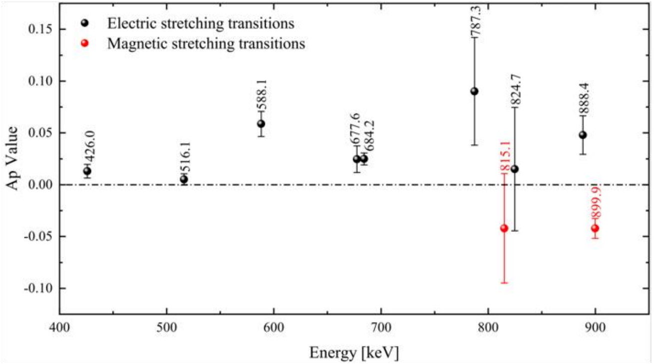
3.1 Level Scheme Reconstruction



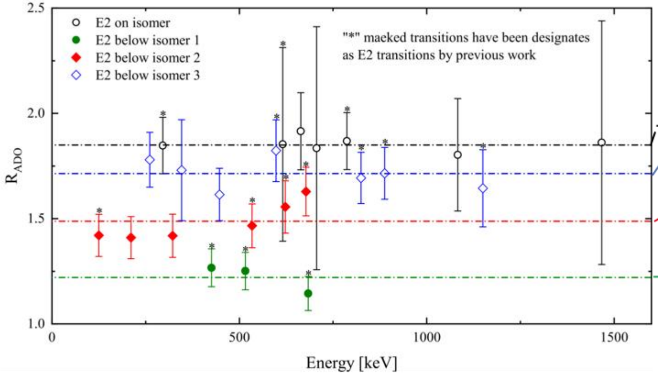




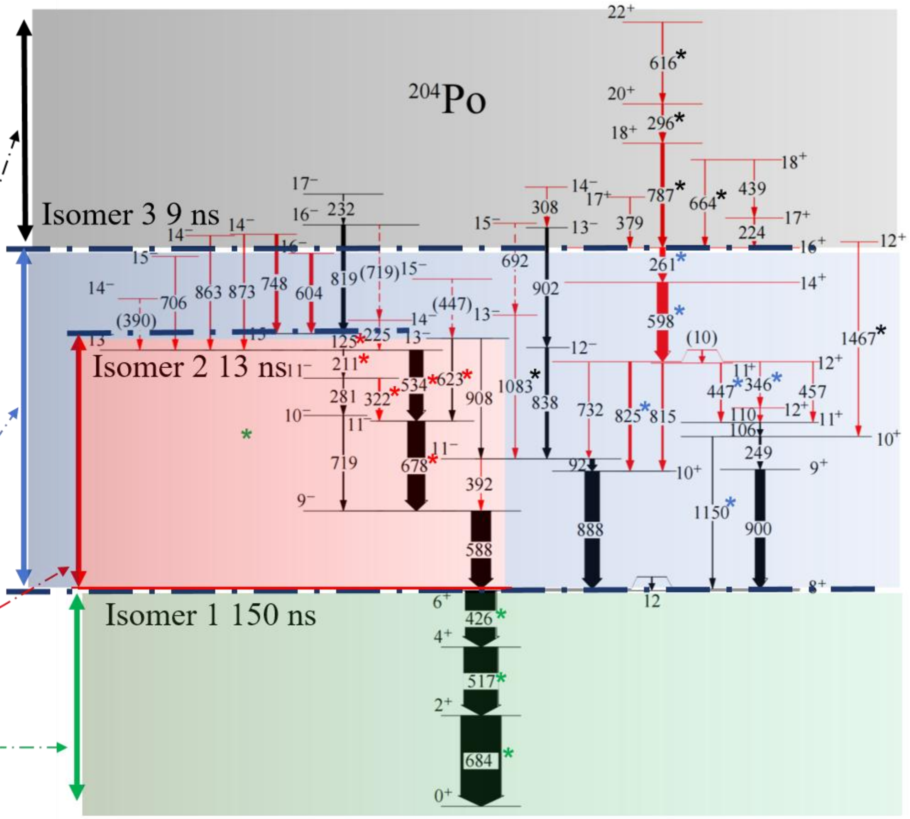
3.2 Spin and Parity Assignment



Linear polarization asymmetry Ap values for certain transitions

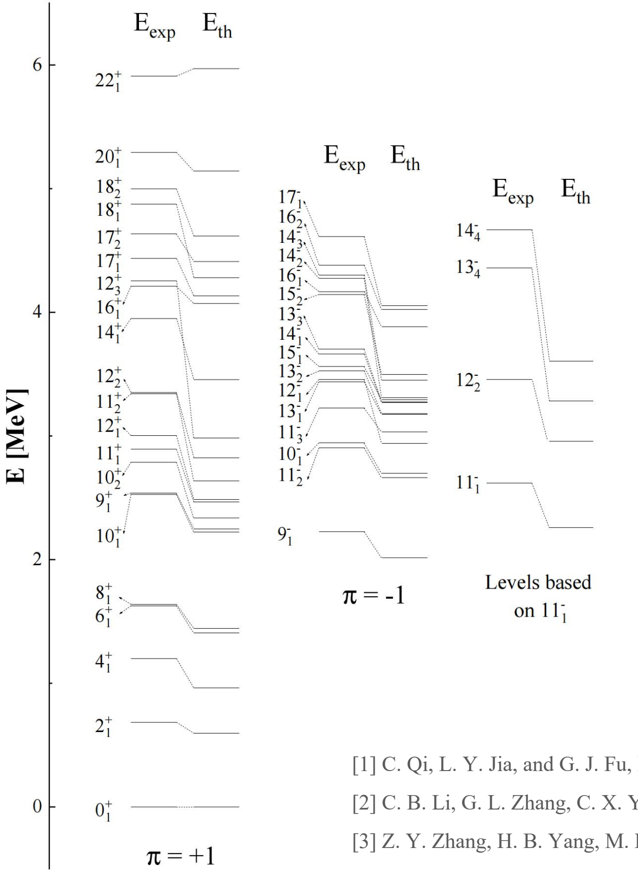


ADO values of E2 transitions along different de-excitation pathways under depolarization conditions



High-spin level scheme of ^{204}Po

3.3 Calculations and Discussion



Model space: 0h9/2, 1f7/2, 1f5/2, 2p3/2, 2p1/2, and 0i13/2

Interaction
- p-p: the Kuo-Herling particle effective (KHPE)
- n(hole)-n(hole): the Kuo-Herling hole effective (KHHE)
- p-n: the monopole-based universal (VMU)

I^π	E_{exp} (keV)	E_{th} (MeV)	Configuration	P_{max}	L_p/L_n
0^+_1	0.0	0.000	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,2,4,0,14)$	20.1	–/–
2^+_1	684.2	0.596	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,2,4,0,14)$	15.29	0.736/1.343
4^+_1	1200.3	0.963	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,3,0,14)$	15.1	0.941/3.188
6^+_1	1626.3	1.407	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,2,4,0,14)$	23.37	5.606/0.879
8^+_1	1638.3	1.444	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,2,4,0,14)$	24.71	8.366/0.355
9^-_1	2226.4	2.016	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,4,0,13)$	27.56	0.153/8.74
10^+_1	2526.7	2.223	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,4,2,0,14)$	15.91	8.443/2.322
9^+_1	2538.2	2.248	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,2,4,0,14)$	18.05	8.073/1.67
11^-_1	2619.1	2.259	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,2,4,0,14)$	16.89	10.667/0.241
10^+_2	2787.4	2.337	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,3,0,14)$	32.43	7.487/3.219
11^+_1	2893.5	2.467	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,3,0,14)$	22.58	8.126/3.677
11^-_2	2904.0	2.663	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,4,0,13)$	31.44	1.175/9.838
10^-_1	2945.1	2.698	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,4,0,13)$	22.58	1.03/8.848
12^+_1	3003.0	2.486	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,2,4,0,14)$	46.17	8.59/4.405
11^-_3	3225.8	3.033	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,4,0,13)$	22.34	1.258/9.619
11^+_2	3341.8	2.637	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,3,0,14)$	27.17	8.297/3.723
12^+_2	3351.4	2.823	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,3,0,14)$	43.72	8.463/4.205
13^-_1	3437.9	3.175	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,4,0,13)$	32.21	5.242/8.006
12^-_1	3457.0	2.957^d	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,3,2,1,14)$	12.38	10.294/1.612
13^-_2	3526.6	3.181	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,4,2,0,14)$	15.06	10.086/2.872
15^-_1	3562.4	3.293	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,4,0,13)$	42.83	7.124/8.38
14^-_1	3662.9	3.270	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,4,0,13)$	37.9	6.921/7.495
13^-_3	3702.1	3.276	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,4,0,13)$	39.65	7.131/6.197
14^+_1	3949.5	3.456	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,3,0,14)$	56.42	8.573/6.218
15^-_2	4143.9	3.497	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,2,4,0,14)$	26.63	10.691/4.365
16^-_1	4166.6	3.884	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,4,0,13)$	33.45	7.774/8.752
16^+_1	4210.8	4.071	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,3,4,0,13)$	25.12	9.395/6.389
12^+_3	4254.6	2.983	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,4,2,0,14)$	26.39	8.415/4.339
14^-_2	4274.7	3.310	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,3,3,0,14)$	18	10.46/3.445
14^-_3	4300.6	3.451	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,4,0,13)$	43.09	7.142/7.33
13^-_4	4358.6	3.283	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,3,3,0,14)$	28.52	10.111/2.848
16^-_2	4381.0	4.023	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,4,0,13)$	51.45	7.279/9.245
17^+_1	4435.3	4.133	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,3,4,0,13)$	27.75	9.671/7.079
17^-_1	4612.8	4.054	$\pi(2,0,0,0,0,0)\otimes\nu(10,8,3,4,0,13)$	57.16	7.303/10.296
17^+_2	4634.0	4.410	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,3,4,0,13)$	30.04	10.014/6.595
14^-_4	4666.6	3.605	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,2,4,0,14)$	18.45	10.449/3.534
18^+_1	4874.5	4.280	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,3,4,0,13)$	30.49	9.887/7.866
18^+_2	4998.1	4.617	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,3,4,0,13)$	33.47	10.327/7.357
20^+_1	5293.1	5.142	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,3,4,0,13)$	30.87	9.955/9.803
22^+_1	5909.2	5.970	$\pi(1,0,0,0,0,1)\otimes\nu(10,8,4,3,0,13)$	48.13	10.306/11.260

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[2] C. B. Li, G. L. Zhang, C. X. Yuan, G. X. Zhang, S. P. Hu, W. W. Qu, Y. Zheng, et al., Physical Review C 101, 044313 (2020).

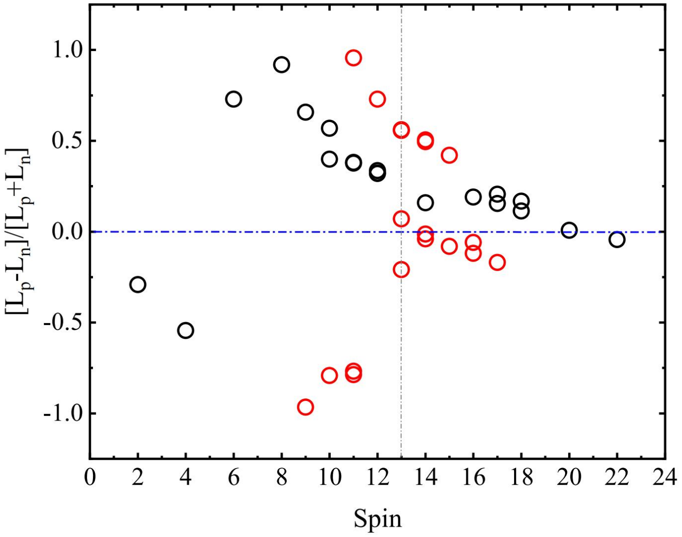
[3] Z. Y. Zhang, H. B. Yang, M. H. Huang, Z. G. Gan, C. X. Yuan, C. Qi, A. N. Andreyev, et al., Physical Review Letters 126, 152502 (2021).

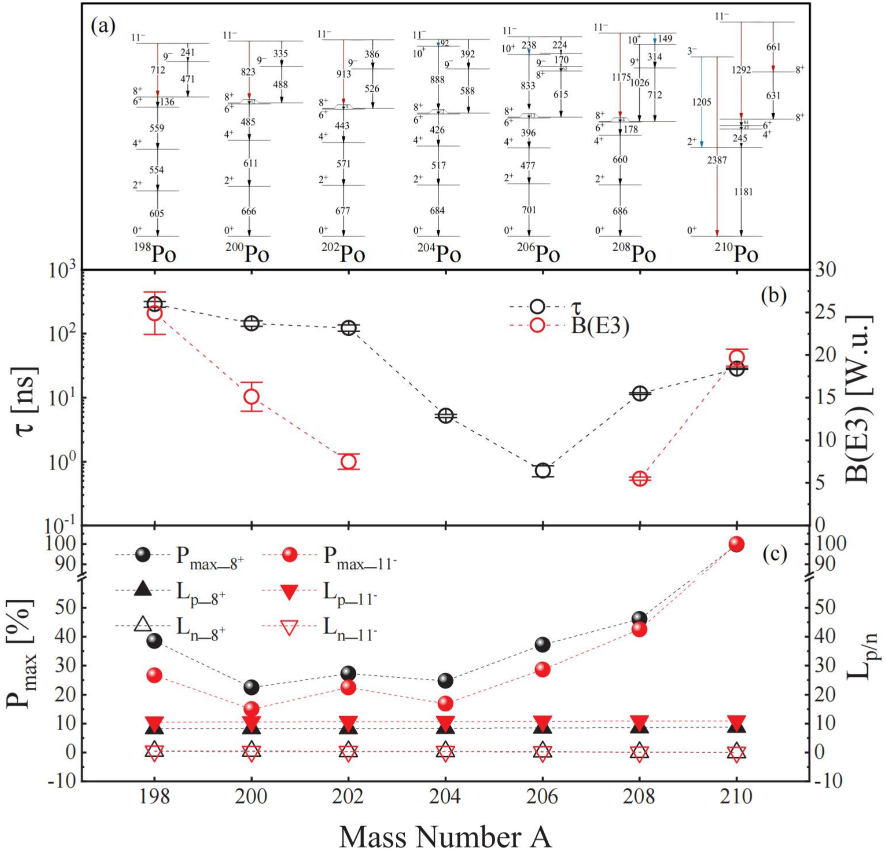
3.3 Calculations and Discussion

To quantify the degree of competition between the proton-aligned component and the neutron-hole component in the theoretical eigenstates, a competition coefficient is defined as

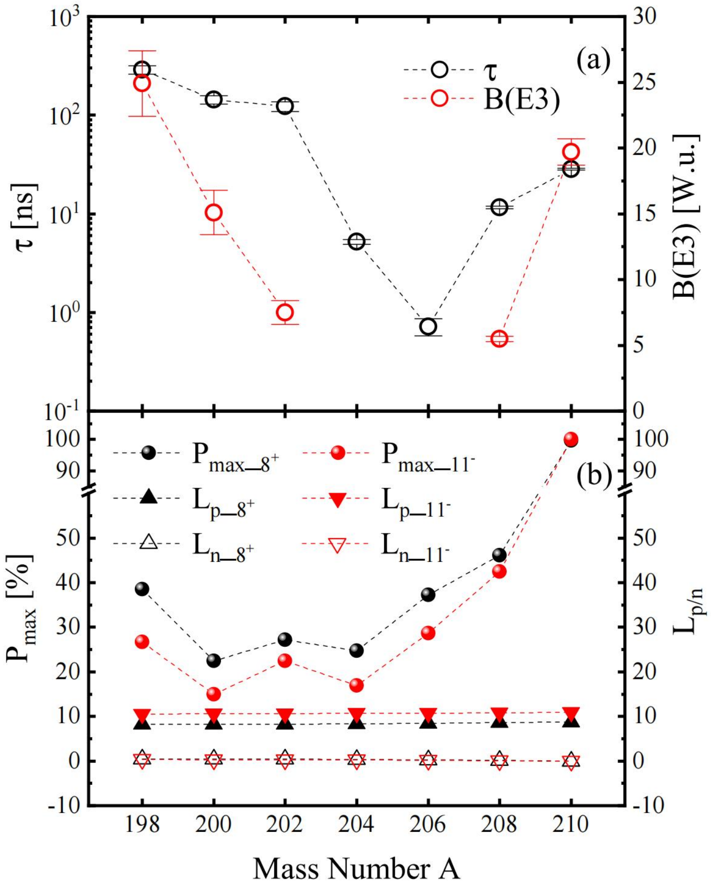
$$k = \frac{L_p - L_n}{L_p + L_n}.$$

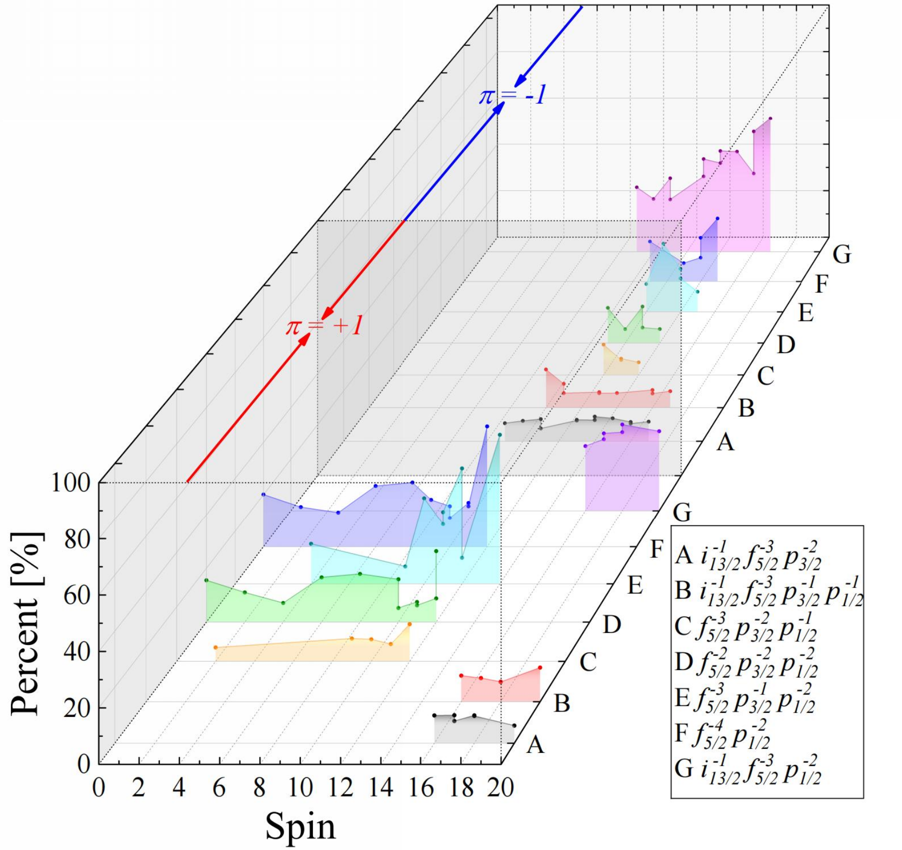
When k is clearly greater than zero, the state is dominated by proton excitations; when k is clearly less than zero, it is dominated by neutron excitations. When k is close to zero, the proton and neutron degrees of freedom contribute comparably, indicating more pronounced competition.





3.3 Calculations and Discussion





4 Summary and Acknowledgements

High-spin states in ^{204}Po were populated through reaction ^{196}Pt(^{13}C,5n)^{204}Po.

Level scheme was revised and extended.

LSSM calculations.

The evolution of the decay pattern of the 11^- state along the even-even $^{196-210}$Po isotopic chain .

The mixing of multiple near-degenerate configurations an d wave-function fragmentation.

The results suggest that ^{204}Po may lie in a transitional region where neutron-hole structural rearrangement and proton-neutron coupling are both highly active. For such a nucleus with strongly fragmented wave functions, neutron cross-shell components across N = 126, proton cross-shell components across Z = 82, and weak collective degrees of freedom outside the present shell-model space may play non-negligible roles in modulating level positions and transition matrix elements.

THANKS FOR YOUR LISTENING